# Assessing the Impact of Potential Climate Changes on Surface Meteorological and Solar Energy Flux Parameters Relevant to Energy Usage and Efficiency

Dr. Paul W. Stackhouse, Jr., NASA Langley Research Center
William Chandler, James Hoell, Colleen Mikovitz,
David Westberg, and Taiping Zhang
Science Systems and Applications, Inc.

Luke Oman, NASA Goddard Space Flight Center

Radley Horton and Daniel Bader, NASA GISS/Columbia Univ.

# Project Purpose

**Purpose:** Contribute to "Assessment Capabilities and Products" for the NCA by using NASA GCM output to assess potential changes

1. of future ***building climate zones and climate design conditions*** (defined using temperature and precipitation) relative to present day and

2. in ***solar energy resource*** available for energy production and supplementation.

# Project Objectives

**Objectives:**

- Provide baseline analysis and and uncertainty assessment for the current state of:
  1. the building climate zone estimates and climate design conditions from GCM control model runs using MERRA and surface measurements (derived from temperature and precipitation); evaluate downscaled meteorological parameters as needed
  2. the surface solar radiation fluxes GCM control model runs using satellite based estimates of solar resource (e.g., GEWEX SRB and CERES) and surface measurements

- Provide an assessment and data sets of the building climate zones and solar resource derived using GCM runs from various climate change scenarios to the present day.
  1. Assess observed shifts and changes in terms of the current climate uncertainties and variability for both quantities.
  2. Develop these climate scenario based products in formats commonly used by industry professionals for further use and assessment.
  3. Also, provide these data sets for use by other interested participants and web based tools to access derived parameters.

# NCA Progress & Tasks

- **Assessing 30 year baseline of Building Climate Zones From MERRA**

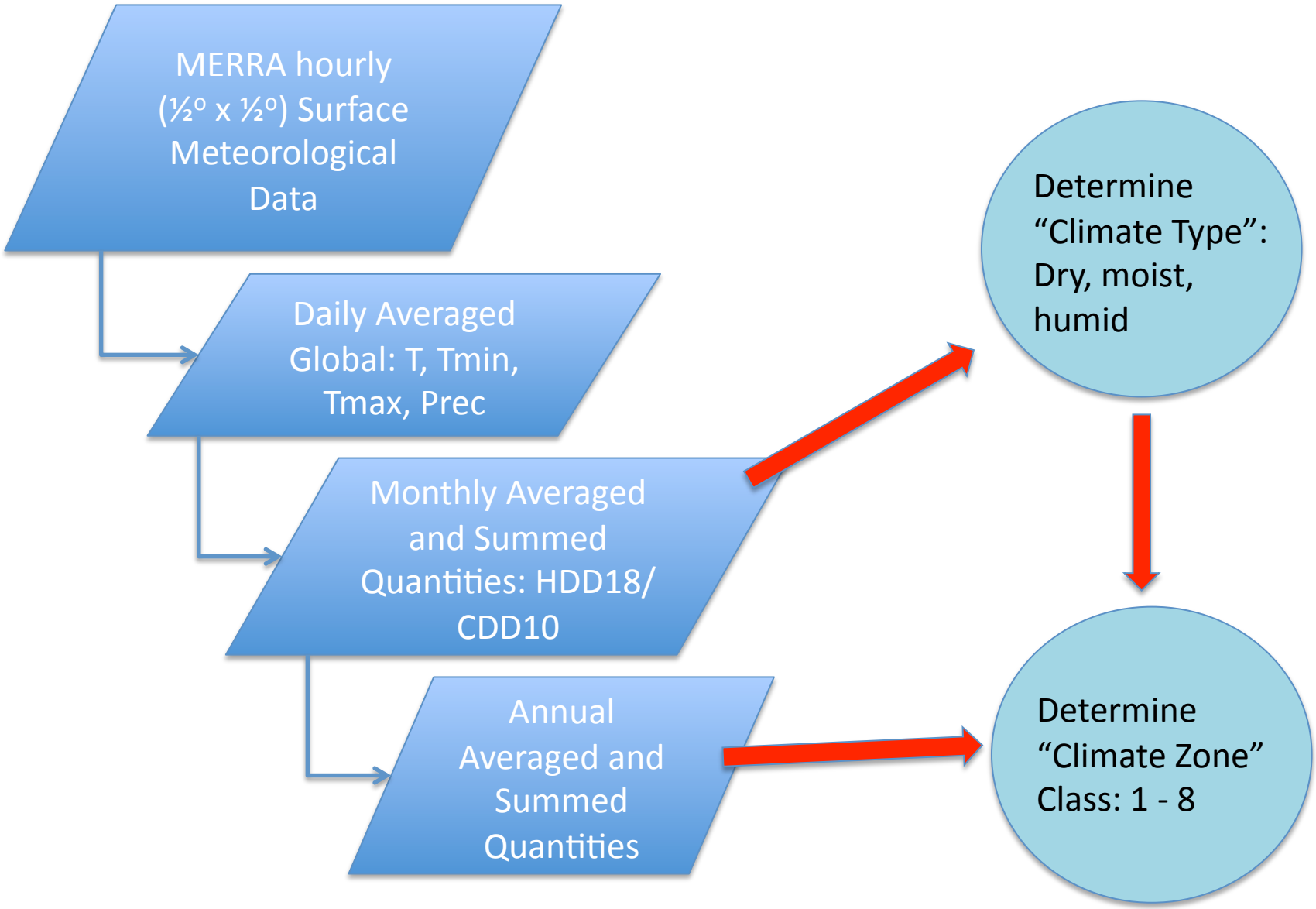
  i. *Processed 30-year MERRA hourly surface parameters to derive daily averaged temperatures, daily maximum and minimum temperatures and daily precipitation rate to the ½ ° x ½ ° degree resolution.*
     - Resolution was specifically requested by the ASHRAE climate executive committee.

  ii. *Validated the MERRA surface meteorological data products against surface sites.*
     - All basic parameters validated including the derived parameters of the heating and cooling degree day (HDD/CDD) calculations required to derive the climate types.
     - All parameters HDD and CDD were assessed for all NCA regions individually.

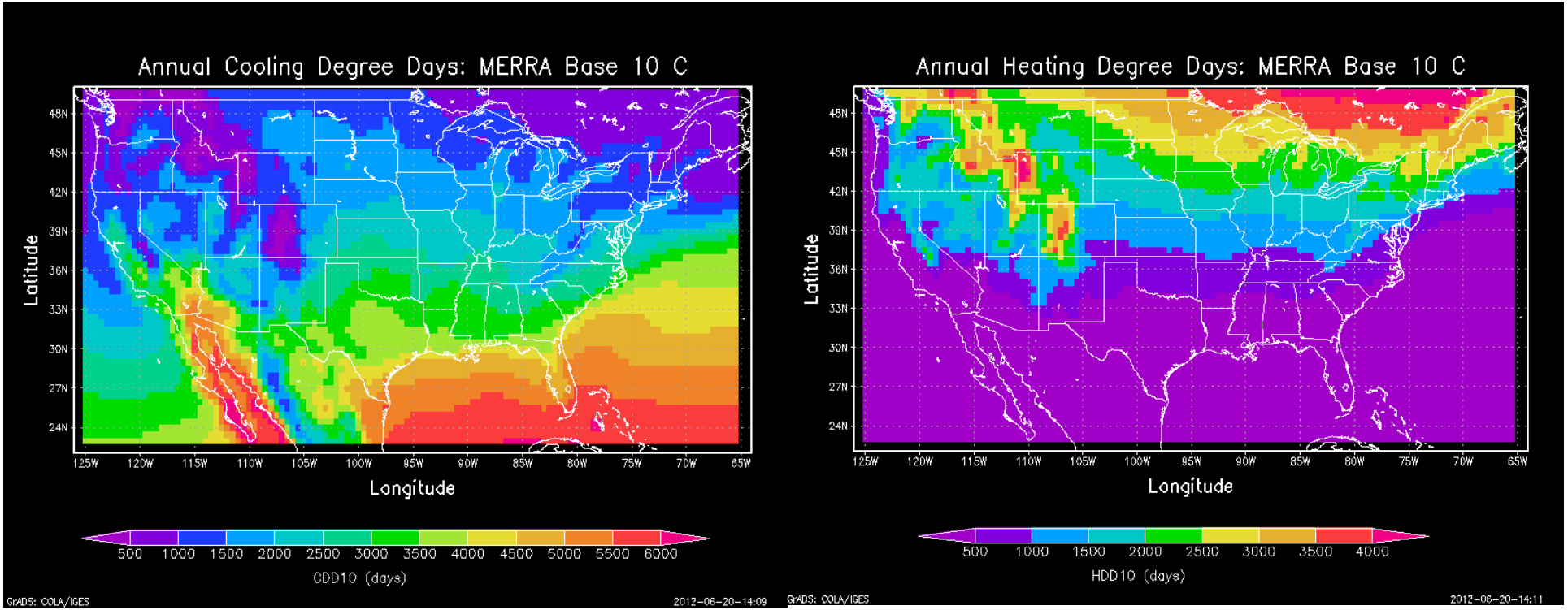
  iii. *Implemented & processed a procedure to produce the DOE/ASHRAE climate zones from regions according to the new definitions:*
     - Produced CONUS and NCA regional maps the 30-year ½° x ½° ASHRAE Building Climate Zone types.
     - Assess the variability of the zones in past 30 years and use to complete assessment of future in year 2 work.

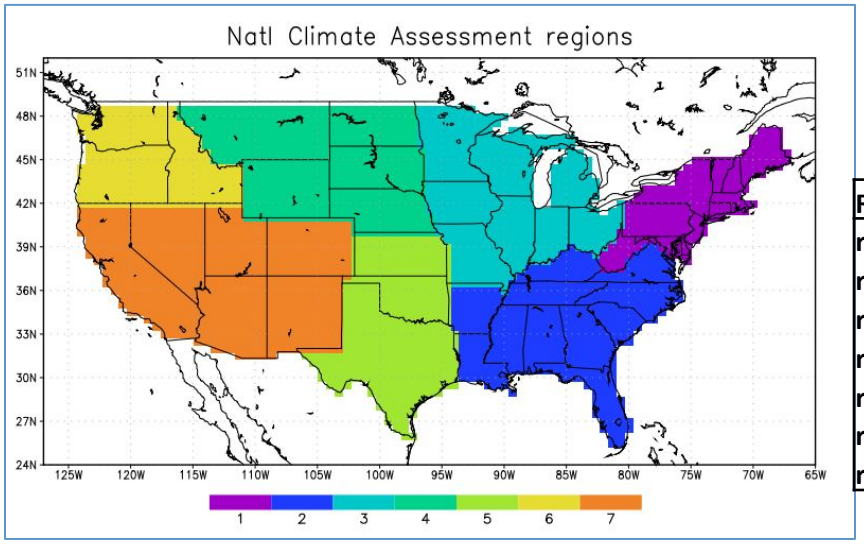
*Climate zones from NASA reanalysis are featured in latest ASHRAE Design Handbook for publication in the next few months.*

# Deriving Building Climate Zones from MERA



# Thirty Year Averaged HDD10 and CDD10
# 1982 – 2011 MERRA Half Degree Hourly Temperatures

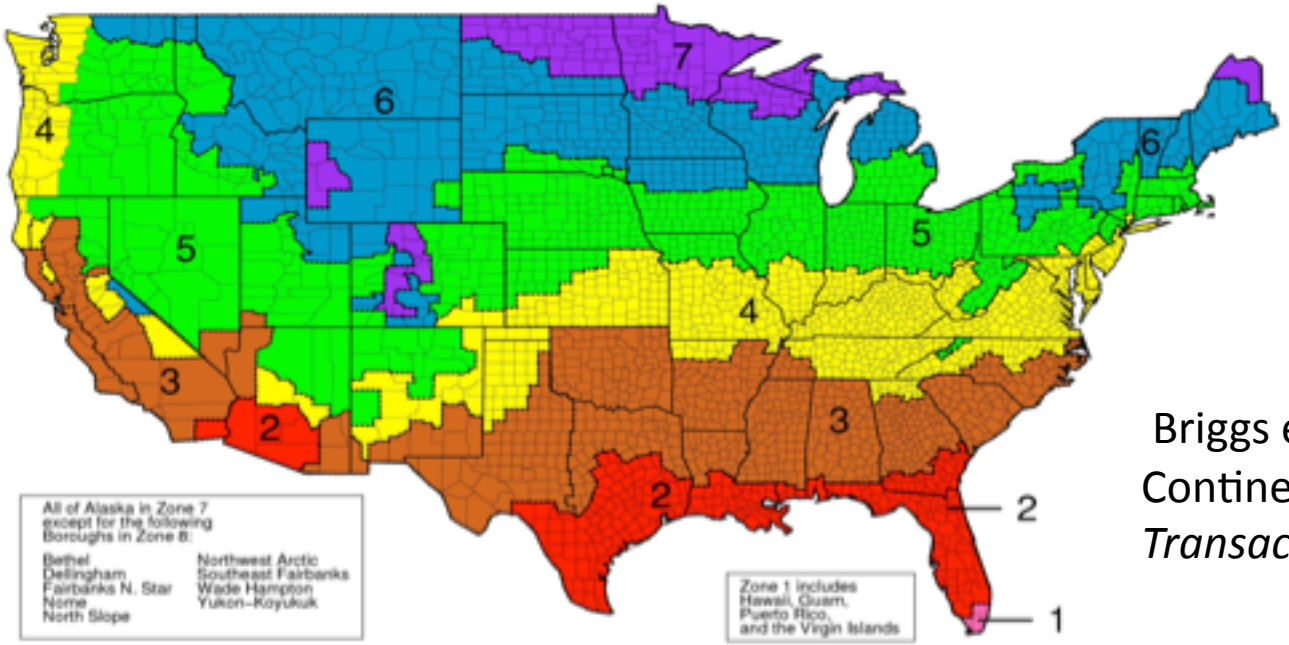



## Thirty Year Annual Regional Averaged HDD & CDD Stats (1982-2011)

| Region | noGrids | YrAveCDD10 | STDEV | STERR | YrAveHDD10 | STDEV | STERR |
|---|---|---|---|---|---|---|---|
| **region1** | 256 | 1398 | 422 | 26 | 1917 | 662 | 41 |
| **region2** | 568 | 3220 | 890 | 37 | 445 | 336 | 14 |
| **region3** | 572 | 1753 | 405 | 17 | 2021 | 690 | 29 |
| **region4** | 553 | 1424 | 466 | 20 | 2283 | 560 | 24 |
| **region5** | 449 | 3321 | 663 | 31 | 482 | 367 | 17 |
| **region6** | 312 | 989 | 375 | 21 | 1779 | 802 | 45 |
| **region7** | 764 | 2156 | 1012 | 37 | 1020 | 788 | 29 |

# Current Climate Zones Maps



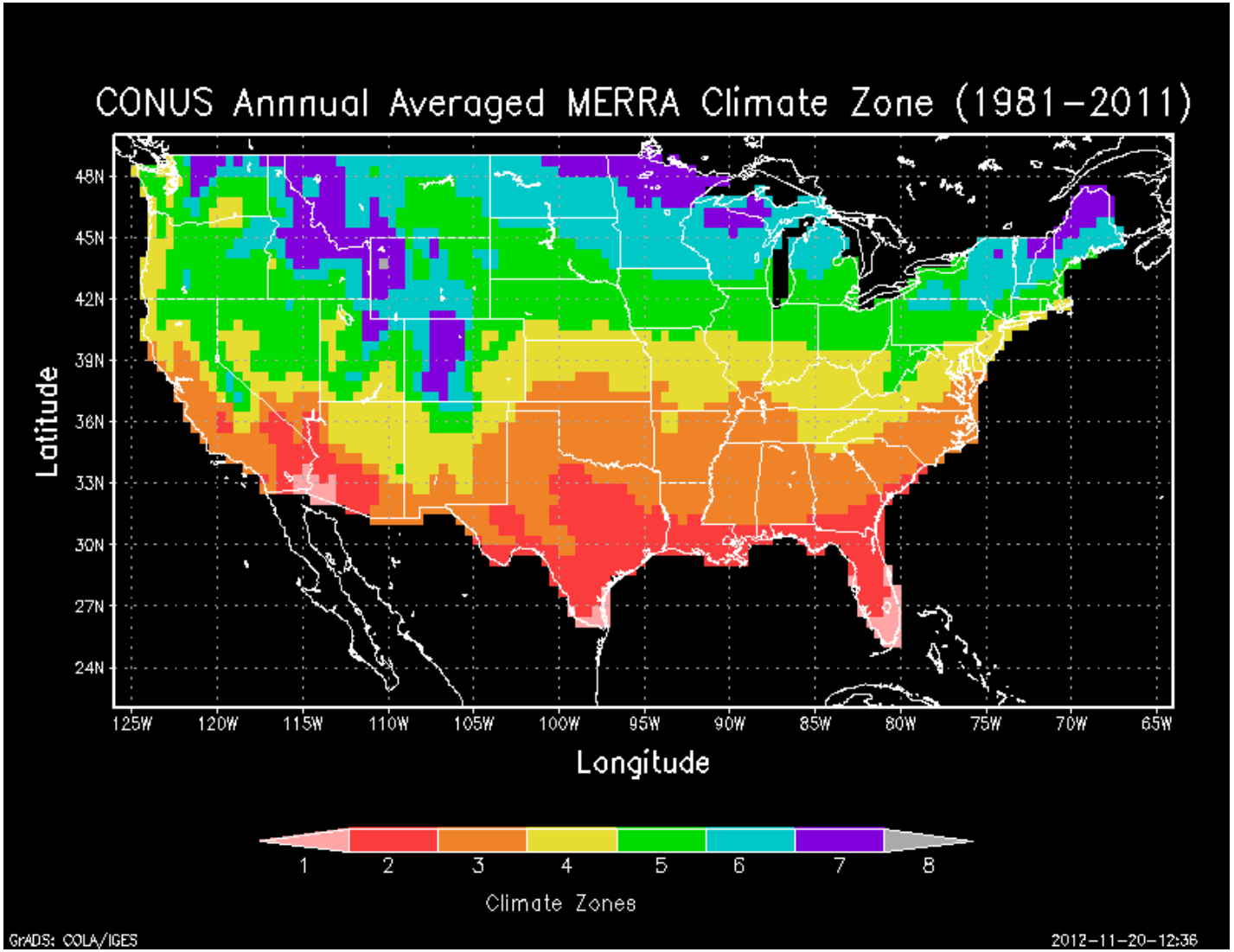

Briggs et al., 2002 of the Continental US (*ASHRAE Transactions*)

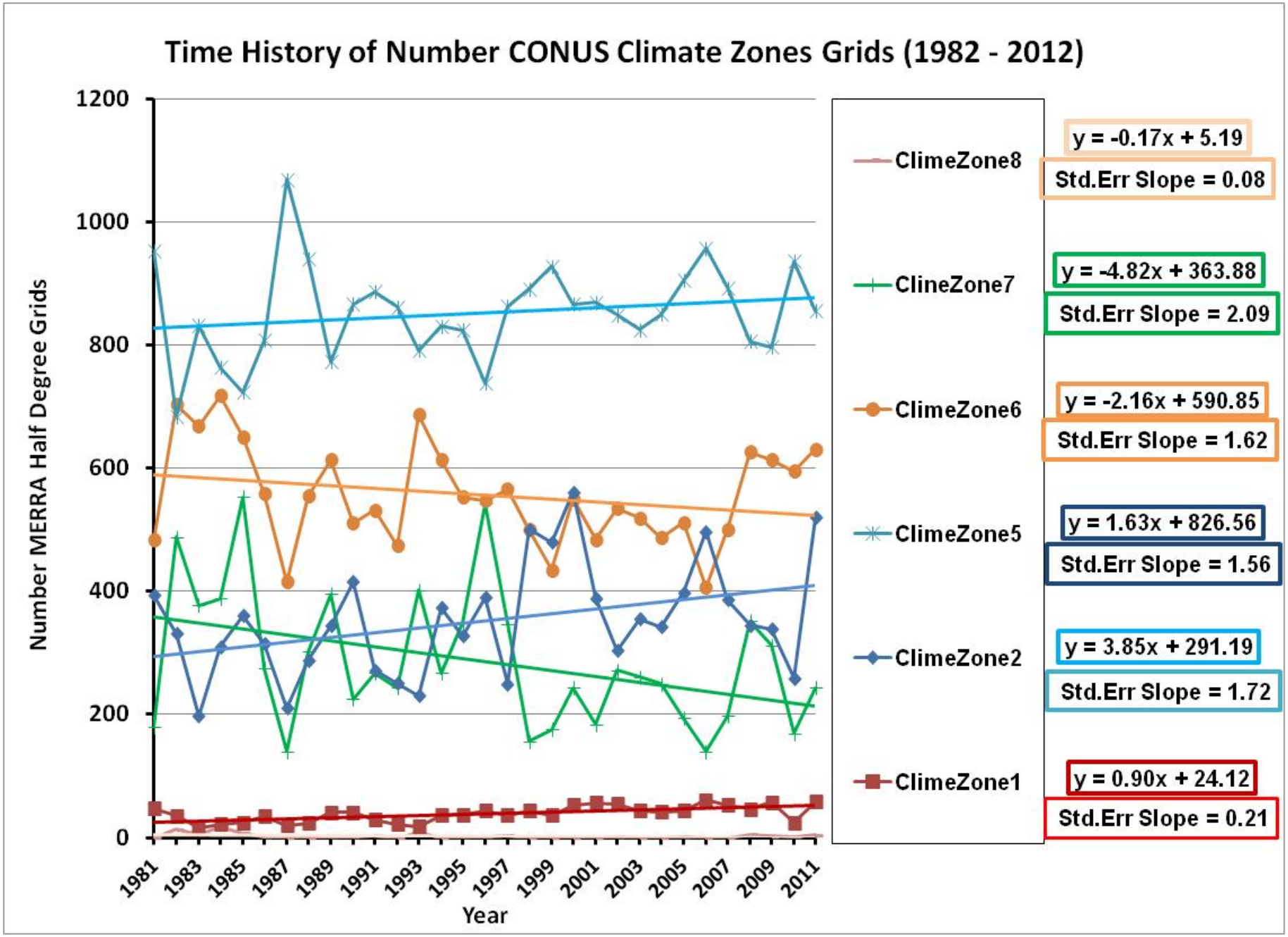
| Characteristics of Briggs buildings climate zones | | | |
|---|---|---|---|
| **Zone #** | **Climate Zone Name and Type** | **Zone #** | **Climate Zone Name and Type** |
| 1A | Very Hot – Humid | 4C | Mixed – Marine |
| 1B | Very Hot – Dry | 5A | Cool – Humid |
| 2A | Hot – Humid | 5B | Cool – Dry |
| 2B | Hot – Dry | 5C | Cool – Marine |
| 3A | Warm – Humid | 6A | Cold – Humid |
| 3B | Warm – Dry | 6B | Cold – Dry |
| 3C | Warm – Marine | 7 | Very Cold |
| 4A | Mixed – Humid | 8 | Subarctic |
| 4B | Mixed – Dry | | |

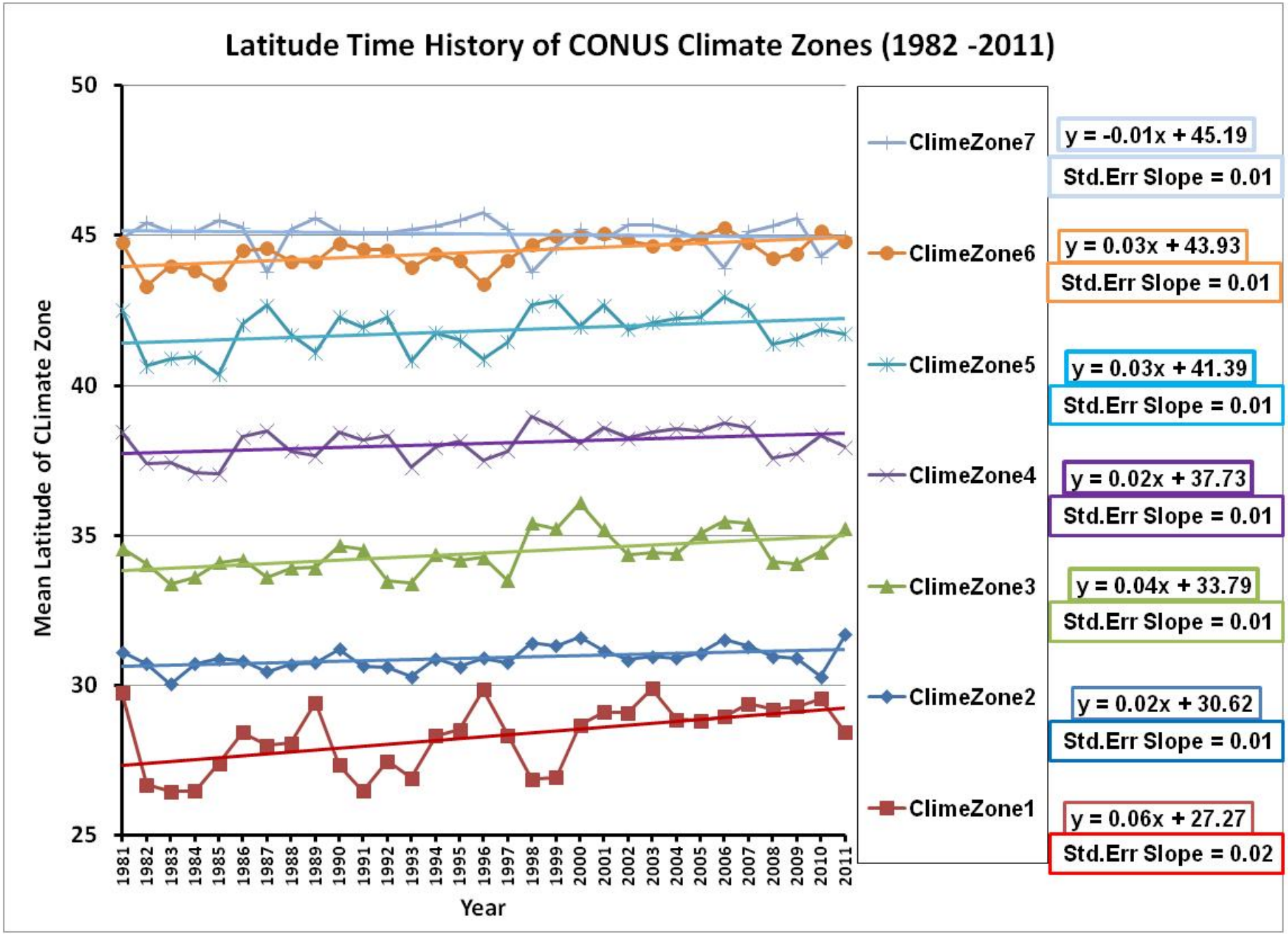
***Key Parameters:***

- Heating/Cooling Degree days using Max/Min daily temperatures
- Annual precipitation

# MERRA Based 30 Year Climate Zones for CONUS




Time History of Number CONUS Climate Zones Grids (1982 - 2012)
Number MERRA Half Degree Grids
1200
1000
800
600
400
200
0
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
Year
ClimeZone8
ClineZone7
ClimeZone6
ClimeZone5
ClimeZone2
ClimeZone1
y = -0.17x + 5.19
Std.Err Slope = 0.08
y = -4.82x + 363.88
Std.Err Slope = 2.09
y = -2.16x + 590.85
Std.Err Slope = 1.62
y = 1.63x + 826.56
Std.Err Slope = 1.56
y = 3.85x + 291.19
Std.Err Slope = 1.72
y = 0.90x + 24.12
Std.Err Slope = 0.21

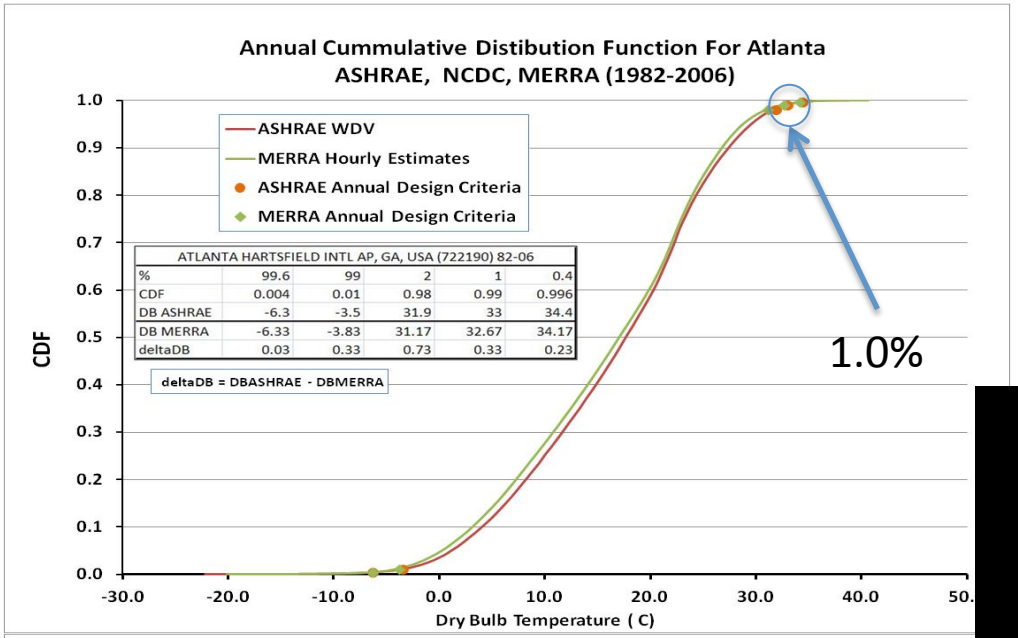

Latitude Time History of CONUS Climate Zones (1982 -2011)
Mean Latitude of CLimate Zone
50
45
40
35
30
25
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Year
ClimeZone7
ClimeZone6
ClimeZone5
ClimeZone4
ClimeZone3
ClimeZone2
ClimeZone1
y = -0.01x + 45.19
Std.Err Slope = 0.01
y = 0.03x + 43.93
Std.Err Slope = 0.01
y = 0.03x + 41.39
Std.Err Slope = 0.01
y = 0.02x + 37.73
Std.Err Slope = 0.01
y = 0.04x + 33.79
Std.Err Slope = 0.01
y = 0.02x + 30.62
Std.Err Slope = 0.01
y = 0.06x + 27.27
Std.Err Slope = 0.02

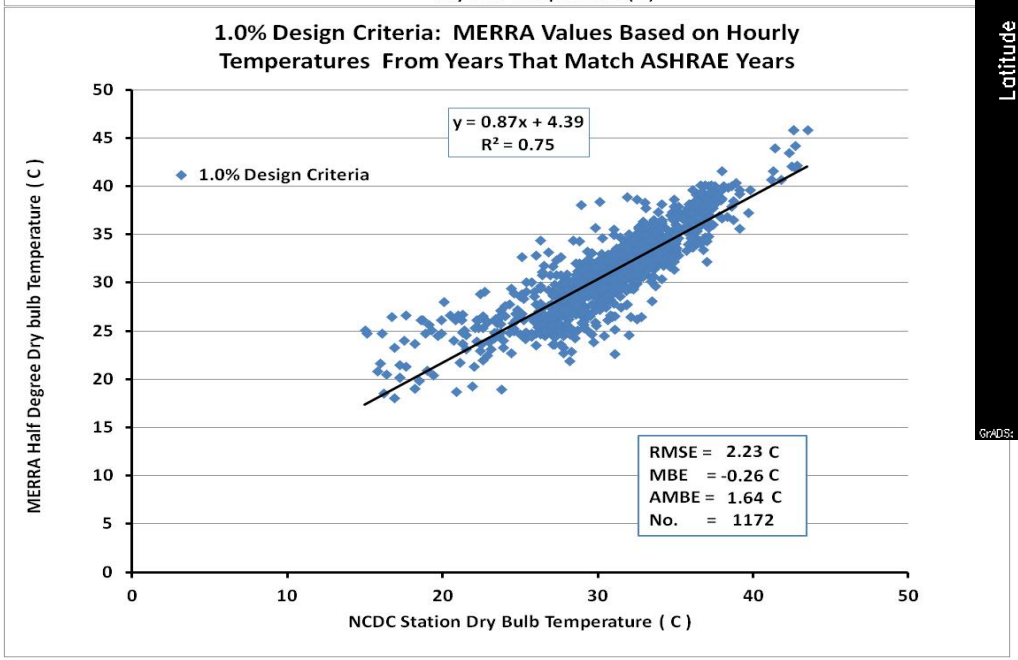
# NCA Progress & Tasks

- ASHRAE Climatic Design Conditions
  - *i.* ***Implemented a procedure using ½° x ½° hourly MERRA data to derive dry bulb temperature****s that* correspond to the 99.6%, 99.0%, 2.0%, 1.0%, and 0.4% of the annual cumulative frequency of occurrence (i.e., the 99.6% dry bulb temperature for a grid box location is the temperature for which 99.6% of all hourly temperatures are warmer than). Thus, these temperatures are essentially a measure of extremes used by the building industry for design.
  - *ii.* ***Validated the results using various ASHRAE surface sites and an ASHRAE developed tool called "Weather Data Viewer" (ASHRAE 2009b).*** ASHRAE only derives these quantities from surface sites is looking to supplement and improve this data set. The accuracy of the distributions is found to be good enough for this purpose.
  - *iii.* ***Produced the first known maps for each of dry bulb extreme temperature parameters noted above for the NCA regions****.* These maps will be key for comparison to maps from potential climate scenarios.

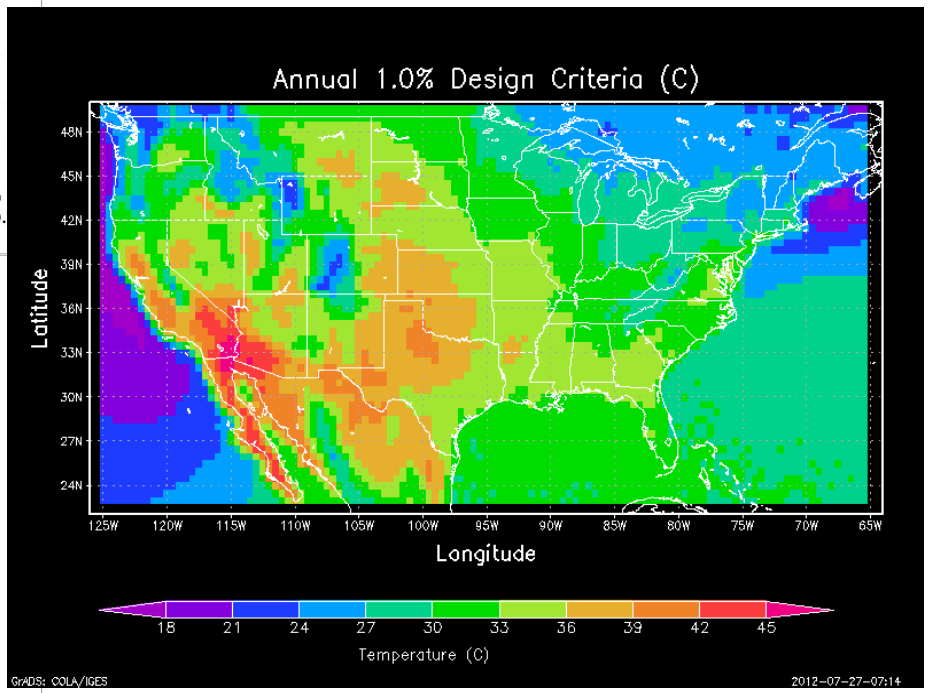
*Accepted a paper to ASHRAE Transactions presenting and discussing these results*.

# ASHRAE Climatic Design Conditions

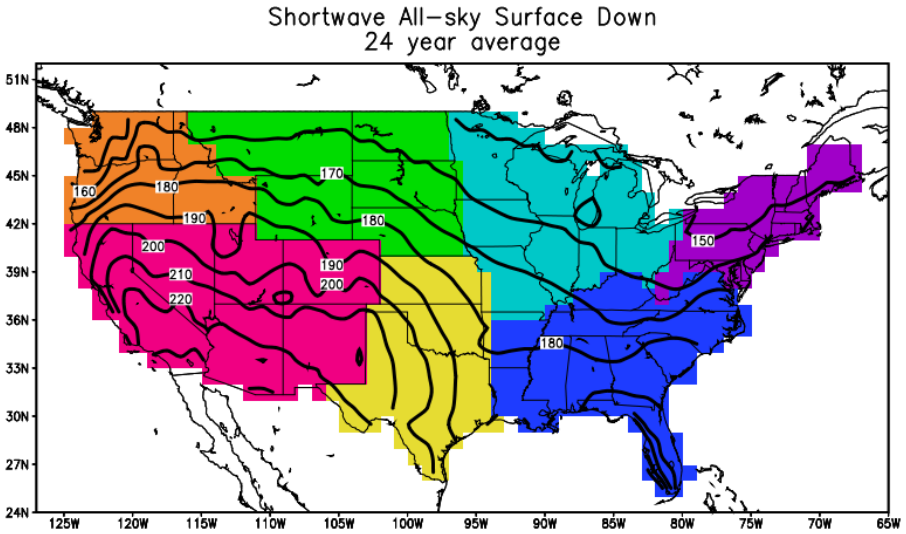


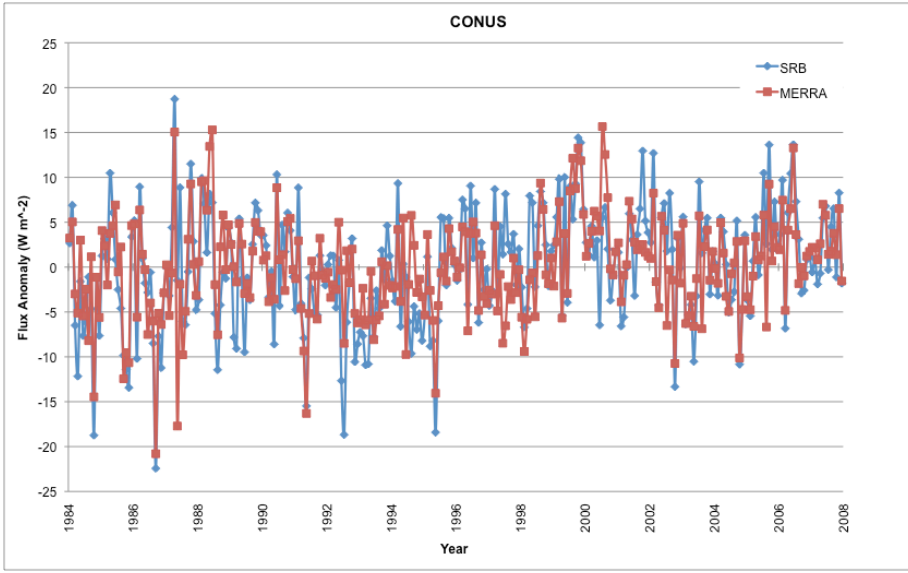

1.0% Dry Bulb Conditions

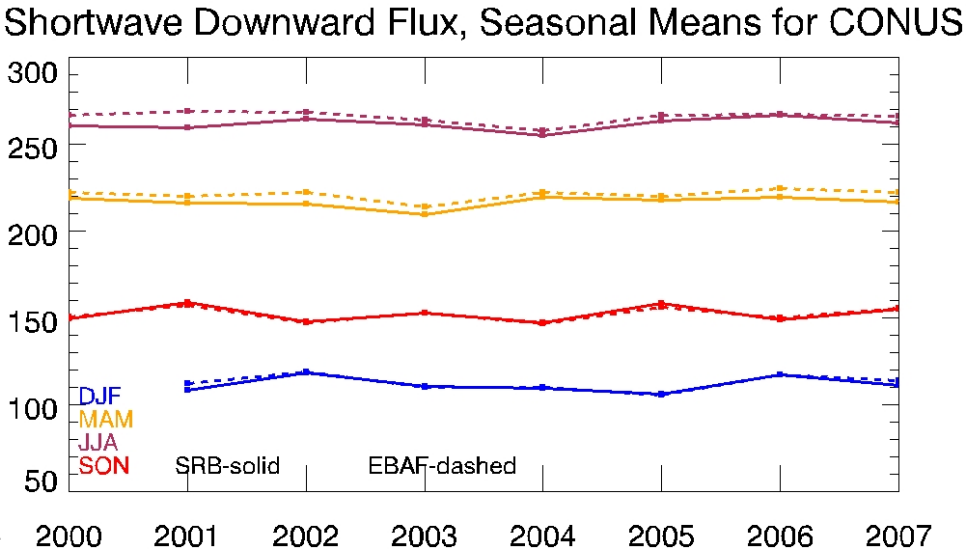


# Solar Resource




- Assessed solar resource from GEWEX SRB
- Compared to MERRA and despite biases saw good agreement in variability
- Added assessment of the new CERES Surface EBAF data set showing good agreement between SRB and CERES for overlap years => established final uncertainties for each region



# NCA Planned Activities

- *MERRA Based Building Climate Zones (requires daily temporal resolution)*
  - i. ***Process long-term climate scenarios from at least the GEOS-5 GCM("Fortuna_2") runs for 3 separate 30 year periods producing climate zones from each.*** Compare/ contrast the various inputs to the climate zone classification. Evaluate changes in the climate zones relative to the current climate.
  - ii. ***Collaborate with GISS to evaluate new temporal downscaling technique and test for NCA applicability.*** If statistical performance is demonstrated, assess same periods for the ensemble of models (leveraged with CASI support for GISS but may be limited to sites).
- *ASHRAE Climatic Design Conditions (hourly temporal resolution needed)*
  - i. ***Process the 2 GEOS-5 GCM climate scenarios for the 30 year periods.*** *Compare the sensitivity of the design parameters to the base state.*
    - ***GCM output provides 3-hourly data assessed for base state to compare relative changes in design conditions.*** If the extremes warm (cold) are significantly more under (over) estimated, we will attempt an adjustment such as a spline fit to simulate the hourly data.
  - ii. ***Report results to ASHRAE for comment via presentations at meetings.***
- *NASA Derived Solar Resource (monthly temporal resolution needed)*
  - i. ***Complete analysis with SRB, CERES, MERRA and GCM base states.*** The use of the CERES data set will help set baseline uncertainty.
  - ii. ***Assess solar irradiance availability changes of the GCM scenarios relative to the base state****.* Compare 30 year means and variability to base state relative to uncertainties.
- Develop Web-based tools for Climate Zones and Design Conditions